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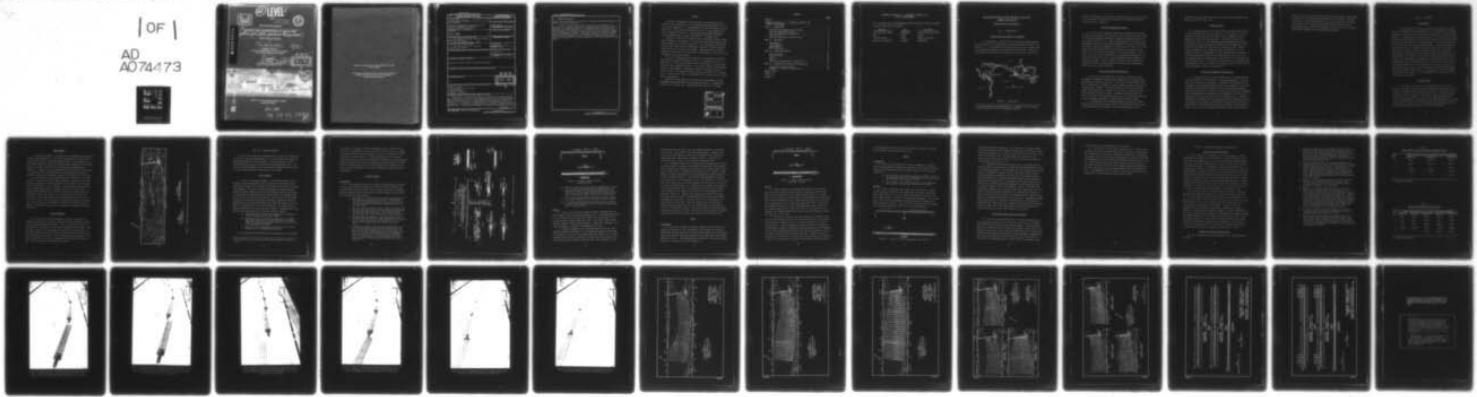
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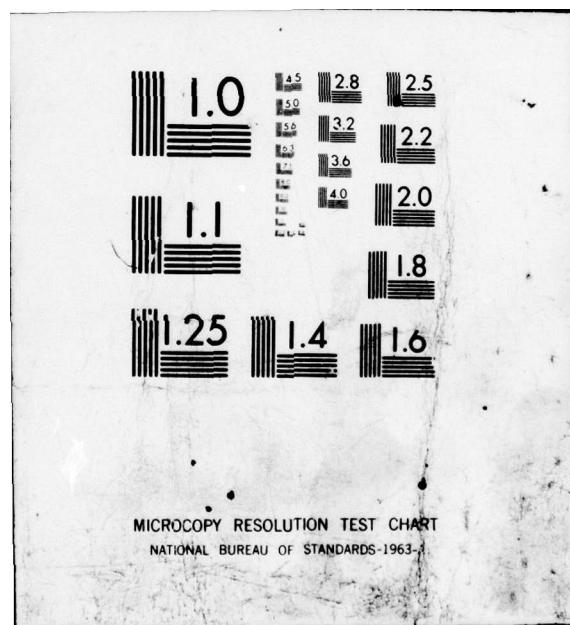
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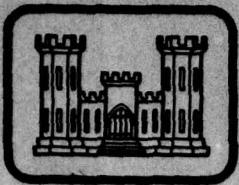
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6 NAVIGATION CONDITIONS AT LOCK AND
DAM 53, OHIO RIVER, KENTUCKY AND ILLINOIS

Hydraulic Model Investigation

by

10 Louis J. Shows, John J. Franco

12 40P.

Hydraulics Laboratory

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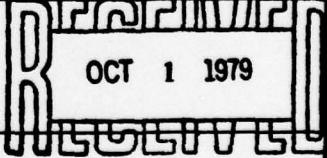
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20. ABSTRACT (Continued).

CONT → develop with the structure as planned and to develop modifications required to provide satisfactory navigation.

In order to provide results before construction was completed on the original plan, a semifixed-bed model utilizing existing facilities was used for the study. The model reproduced to an undistorted scale of 1:120 the dam, upper portions of the locks, and about 2 miles of the river upstream. Results of the investigation indicated the hazardous condition that could be expected with the structures as planned. Satisfactory navigation conditions could be developed with the temporary lock by extending the upper guard wall and providing sufficient ports in the wall to pass most of the flow intercepted by the wall.

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PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, in an indorsement dated 18 January 1977 to the Division Engineer, U. S. Army Engineer Division, Ohio River, Cincinnati, Ohio. The study was conducted for the U. S. Army Engineer District, Louisville, by the U. S. Army Engineer Waterways Experiment Station (WES) during the period January 1977 to December 1977.

During the course of this model study, the Louisville District was kept informed of the progress of the study through monthly reports and special reports at the end of each test. Also, personnel of the Louisville District made visits to WES during the study to observe special model tests and to discuss test results. Representatives of various navigation interests also visited WES to observe model conditions utilizing some of the proposed plans.

The model investigation was conducted in the Hydraulics Laboratory (HL) under the general supervision of Mr. H. B. Simmons and Mr. F. A. Herrmann, Jr., Chief and Assistant Chief, respectively, of the HL, and under the direct supervision of Mr. J. E. Glover, Chief of the Waterways Division. The engineer in immediate charge of the model was Mr. L. J. Shows, Chief of the Navigation Branch, assisted by Messrs. R. T. Wooley and J. M. Ross. This report was prepared by Mr. Shows and by Mr. John J. Franco, Consultant.

Directors of WES during the course of the investigation and the preparation and publication of this report were COL J. L. Cannon, CE, and COL N. P. Conover, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

| <u>Multiply</u> | <u>By</u> | <u>To Obtain</u> |
|-----------------------|------------|-------------------------|
| cubic feet per second | 0.02831685 | cubic meters per second |
| feet | 0.3048 | meters |
| feet per second | 0.3048 | meters per second |
| miles (U. S. statute) | 1.609344 | kilometers |

NAVIGATION CONDITIONS AT LOCK AND DAM 53, OHIO RIVER
KENTUCKY AND ILLINOIS

Hydraulic Model Investigation

PART I: INTRODUCTION

Location and Description of Prototype

1. Lock and Dam 53 is located on the Ohio River between Paducah, Ky., and Cairo, Ill., approximately 3 miles* northeast of Olmsted, Ill. (Figure 1). It is designed to maintain during low flows a single upper pool extending upstream to Lock and Dam 52 at mile 938.9. Since its construction in the late 1920's and early 1930's, Lock and Dam 53 has

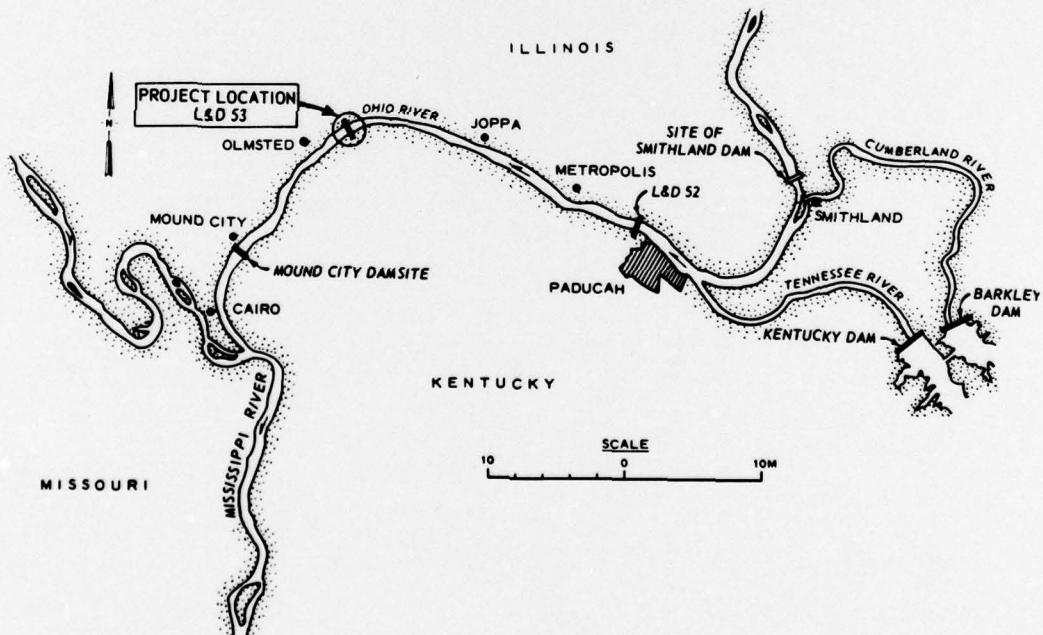


Figure 1. Location map

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

become a bottleneck for the heavily congested barge traffic on the river. For this reason, modification was proposed as a temporary measure to alleviate traffic congestion.

Ohio River Navigation Project

2. The Ohio River navigation project was authorized by the River and Harbor Acts approved 25 June 1910, 18 July 1918, and 30 August 1935. It included maintained channels and a system of locks and dams to provide a usable depth of 9 ft. Before modernization of the project was undertaken, the lock and dam system consisted of 46 control structures, each with a usable lock chamber 110 ft wide by 600 ft long. At 4 of the structures, auxiliary locks 56 ft wide by 360 ft long were also provided. Of the 46 control structures, 42 had movable crests, 1 had a fixed crest, and 3 were nonnavigable, gate-controlled structures. Pool lifts varied from 5.6 to 37.0 ft, and navigation channel widths were generally in excess of 500 ft except at critical bars where there is recurrent shoaling. However, 300-ft-wide channels are maintained at critical bars by periodic dredging.

Plans for Improving Navigability

3. The Ohio River movable dams and their locks were initially designed to accommodate downbound coal shipments since upbound traffic was extremely limited at that time. The size of the lock chamber was based on the ability to pass in a single lockage a normal coal fleet of 10 barges and a towboat. Traffic has steadily risen since, and this growth can be expected to continue in the future. Also, barge sizes have increased in the last decade. Assembled tows measuring up to 1150 ft in length, including the towboat, and 104 ft in width have made multiple lockages necessary at existing dams with 600-ft locks.

4. The magnitudes of the changes emphasize the need for modern facilities to provide efficient service for present-day traffic as well as that which can be anticipated. Current plans provide for the

replacement of all movable dams and their locks with nonnavigable dams having at least one large lock.

Lock and Dam 53

5. Lock and Dam 53 is one of the original structures that has not yet been replaced with a modern structure. It is typical of the old locks with movable dams (110- by 600-ft lock), navigable pass, and movable and fixed weirs and beartraps. A condition survey of the structure by the U. S. Army Engineer Waterways Experiment Station and the Ohio River Division Laboratory during the period September 1973 to March 1974 indicated the structure to be basically sound. Based on results presented in this report and other considerations, it was decided to delay the replacement of this structure and to alleviate the bottleneck through the addition of a temporary 110- by 1200-ft lock. The existing 600-ft lock would then be used mainly as an auxiliary lock and for smaller craft. Accordingly, construction of the temporary lock was undertaken on the river side of the existing lock in FY 1974 with an expected completion date of 8 November 1977.

Need for and Purpose of Model Study

6. During construction of the temporary lock, it became apparent that the intensity of crosscurrents in the upper approach to the existing 600-ft lock would be increased. Conditions for downbound tows approaching the lock became extremely difficult and hazardous, and it was necessary to employ a helper boat to assist tows making the approach during critical periods. Conditions existing at the time also indicated that the proposed short guard wall for the temporary lock would not be adequate for the size tows that would be using the lock. In order to determine the conditions that would develop with the completed structure as proposed and to develop any modifications that might be required, a model study of the project was considered necessary. Specifically, the model was to be used to determine the length of guard wall, size and

number of ports in the guard wall, and any other modifications that might be required for satisfactory navigation with various flows. The model was also to be used to demonstrate for the design engineers and navigation interests the conditions that would develop with the proposed modifications and to satisfy the navigation interests as to the requirements and acceptability from a navigation standpoint.

PART II: THE MODEL

Description

7. By the time that the model study had been authorized, construction of the temporary lock had advanced to such an extent that it became necessary to expedite the study to provide the information needed before completion. Accordingly, the model was constructed utilizing an existing facility and reproducing only the principal features affecting conditions in the upper lock approach. The bed and banks of the model channel were molded in crushed coal to sheet metal templets. The model reproduced, in accordance with the available prototype surveys, the reach from the dam to about mile 961, which was considered sufficient to provide a reasonably good reproduction of the currents affecting navigation in the lock approach. The portion of the model between miles 961 and 963 was molded to the approximate configurations of the prototype that could be accommodated in the existing facilities. The model included the dam and the upper portions of the locks and auxiliary lock walls, which were fabricated of sheet metal. The bed and banks of the model were molded to the configurations indicated by the prototype survey dated September 1967 except for the reach in the lock approach which was molded to the survey dated August 1972.

Scale Relations

8. The model was built to an undistorted scale ratio of 1:120, model to prototype, to obtain accurate reproduction of velocities, cross-currents, and eddies that would affect navigation. Other scale ratios resulting from the linear scale ratio were: area, 1:14,400; velocity and time, 1:10.95; discharge, 1:157,743; and roughness (Manning's n), 1:2.22. Measurements of discharge, water surface elevations, and current directions and velocities can be transferred quantitatively from model to prototype equivalents by means of these scale relations.

Appurtenances

9. Water was supplied to the model from a comprehensive circulating system. The discharge was controlled and measured at the upper end of the model by means of a valve and venturi meter. Water surface elevations were measured by means of five point gages located along the right bank of the model channel and above and below the navigable pass (Figure 2). Stages for the discharges tested were controlled by raising or lowering the bear traps and weirs and the navigation pass and by raising or lowering the tailgate located at the lower end of the model.

10. Velocities and current directions were determined in the model by means of cylindrical wooden floats weighted on one end so that they would be submerged to a depth equivalent to the draft of loaded barges using the waterway (9 ft in prototype). Spot velocities were measured with a midget current meter. A model towboat with tow was used to determine and demonstrate the effects of currents on tows entering and leaving the locks. The overall size of the tow was 105 by 1200 ft. The towboat was equipped with twin screw-type propellers propelled by two small electric motors operating from batteries located in the model tow. The towboat could be operated in forward or reverse at various speeds. The towboat and the set of rudders were electronically remote-controlled.

Model Adjustment

11. Before the study was undertaken, the model was checked and adjustments were made in the flow distribution where necessary to reproduce available prototype velocities. Since the model bed consisted of crushed coal no adjustment of the channel roughness could be made. With the short reach of river reproduced, any errors in the simulation of prototype roughness would not have any appreciable effect on water surface elevations or velocities. Tests conducted after adjustment of the model indicated that the model reproduced with reasonable accuracy the spot current velocities furnished for the reach.

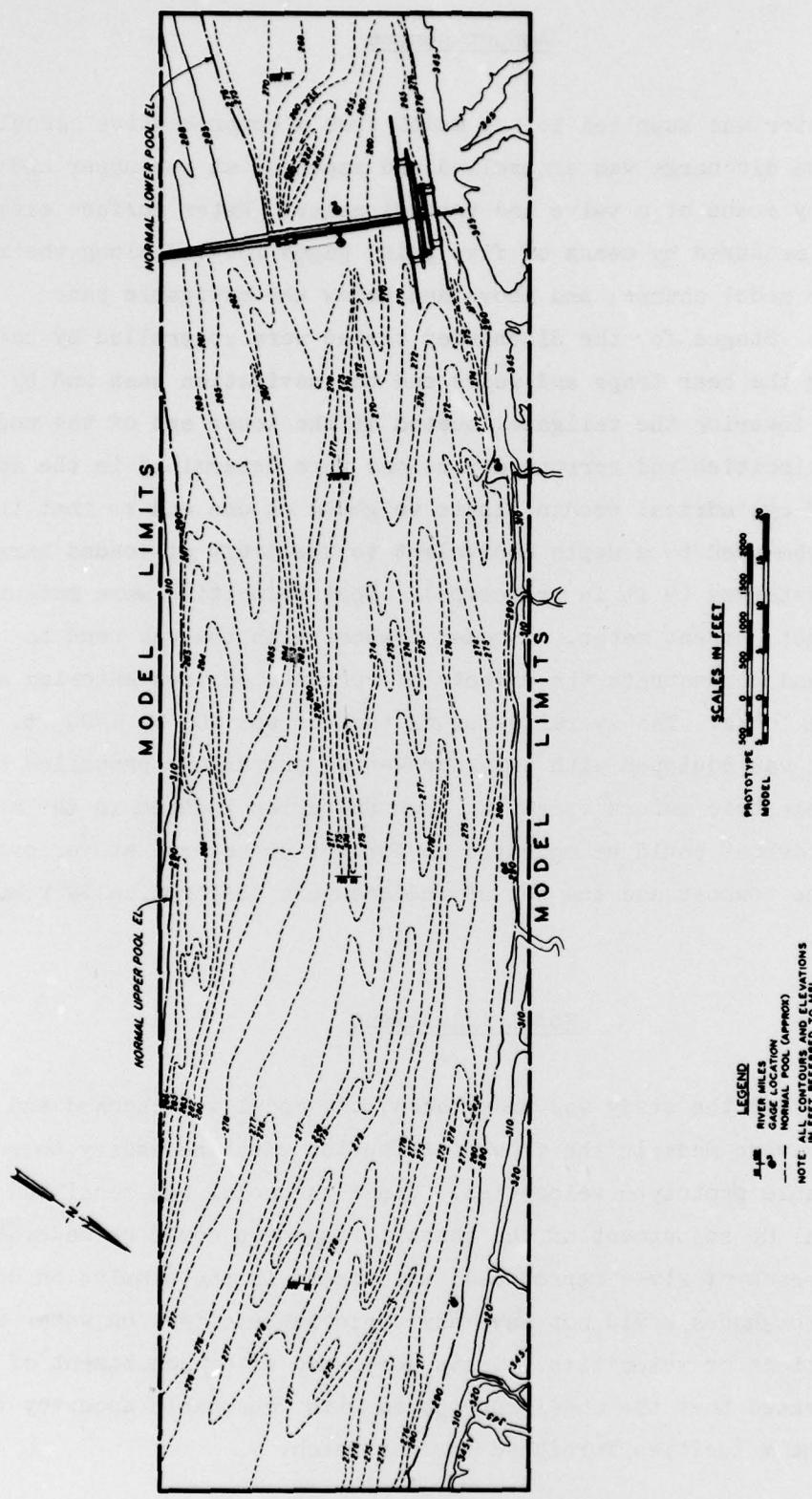


Figure 2. Model layout showing existing conditions with proposed 1200-ft lock

PART III: TESTS AND RESULTS

12. Tests were concerned primarily with the study of currents and velocities in the upstream approach to the new lock and the effects of various modifications on the movement of tows approaching the lock. The modifications tested were developed during preliminary tests. The results of the preliminary tests were based on observations with little or no data taken and are not discussed in this report.

Test Procedure

13. Tests of the plans consisted of reproducing selected representative flows, determining current velocities and directions, and observing the behavior of the model tow moving into and out of the upper lock approach. Open river flows were reproduced by introducing the proper discharge, lowering the weirs and navigation pass to the bottom of the channel, and manipulating the tailgate until the computed upper pool elevation for the flow was obtained. Controlled river flows were obtained by introducing the required discharge, raising the weirs and navigation pass, and manipulating the bear traps and tailgate until the upper pool elevation for that flow was obtained. All flows were permitted to stabilize before any data were recorded. Representative flows selected and used during most of the tests were as follows:

- a. Controlled flow of 32,000 cfs; upper pool el of 290.0*
(all flow through the two bear traps).
- b. Controlled flow of 110,000 cfs; upper pool el of 290.0
(both bear traps open, the 500-ft movable weir between traps and navigation pass down, and 90 ft on the left end of the navigation pass down).
- c. Open river flow of 203,000 cfs; upper pool el of 294.2
(traps, weir, and navigation pass open).

14. Velocities were determined by timing the travel of the floats

* All elevations (el) cited herein are in feet referred to mean sea level.

(described in paragraph 10) over a measured distance. Current directions were ascertained by plotting the paths of the floats with respect to ranges established for that purpose. In plots of currents in turbulent areas or where eddies or crosscurrents existed, only the main trends are shown for clarity. The effects of currents on a tow approaching and leaving the lock and in navigating through the reach were determined by observing the effects of the currents on the movement of the model tow while under power or drifting, depending on currents affecting movement.

Original Design

Description

15. The original design was the same as existing prototype conditions at Lock and Dam 53 except that the 110-ft-wide by 1200-ft-long lock which was under construction was included in the model as planned. The basic designs of the structures are shown in Figure 3 and included the following principal features:

- a. Two parallel locks were located along the right bank with the tops of the lock walls at el 295.0. The landside lock had clear chamber dimensions of 110 by 600 ft, and the new, riverside lock had clear chamber dimensions of 110 by 1200 ft.
- b. The small 600-ft lock had a 571-ft-long solid upper guide wall, and the larger new lock had a 600-ft-long nonported cellular-type upper guard wall. The 6.2-ft spacings between cells were closed with metal curtains (Figure 4).
- c. The navigable pass adjacent to the new lock was 934 ft wide and could be raised or lowered depending on discharge. In the raised position, the structure had a top el of 290.0, in the lowered position, it had a top el of 273.1.
- d. A 500-ft-wide movable weir was located between the left end of the navigation pass and the two bear traps; the pass and weir were separated by a 10-ft-wide pier. The 340.1-ft section of the weir adjacent to the navigation pass could be lowered to el 279.0, and the remaining 160.0-ft section of weir could be lowered to el 280.0. In the raised position, both weir sections had a top el of 290.0.

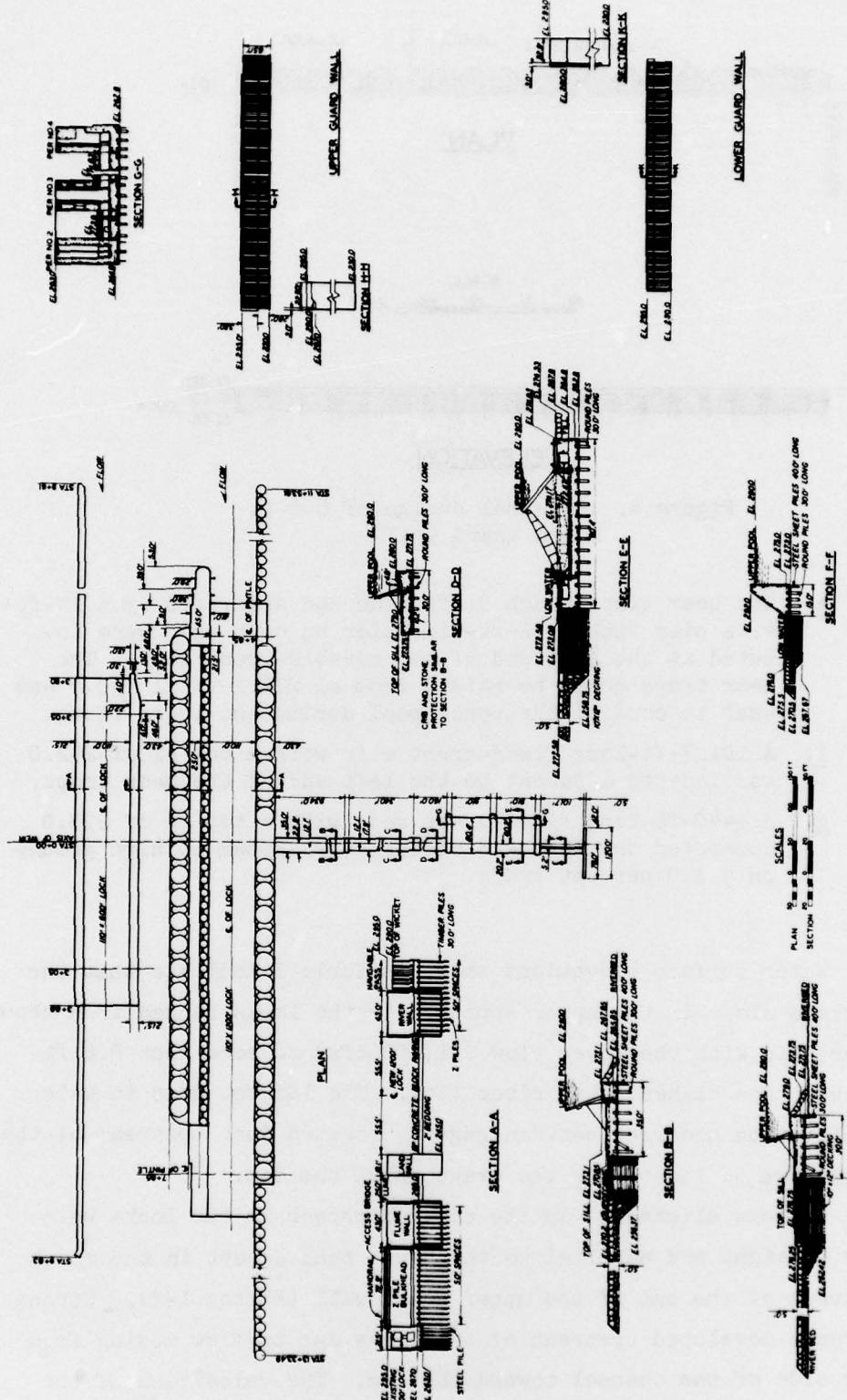


Figure 3. Plan and sections of structures

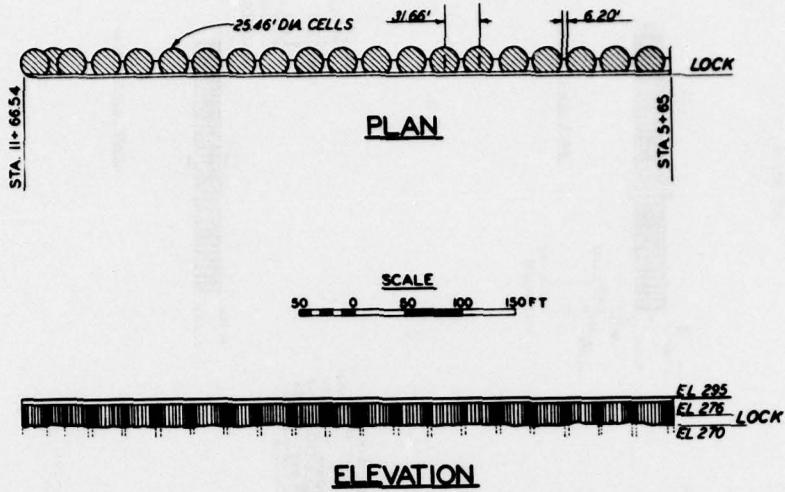


Figure 4. Original design of 600-ft solid guard wall

- e. Two bear traps, each 91 ft wide and separated by a 14-ft-wide pier with a 12-ft-wide pier on each end, were located at the left end of the movable-crest weir. The bear traps could be raised from el 274.2 to el 290.0 and used to control the upper pool during the lower flows.
- f. A 101.7-ft-long fixed-crest weir with a top el of 292.0 was located adjacent to the left end of the bear traps.
- g. A 1440-ft-long fixed-crest weir with a top el of 293.0 connected the left end of the weir system to high ground on a 1.0 percent grade.

Results

16. Water surface elevations shown in Table 1 indicate that the water surface slope in the upper approach to the locks ranged from about 0.1 ft per mile with the lower flow (32,000 cfs) to more than 0.6 ft per mile with the higher, open river flow. The largest drop in water surface elevation occurred between gage 3, located just upstream of the locks, and gage 5, located in the drawdown at the dam.

17. Current alignments in the upper approach to the locks were generally straight and parallel to the right bank except in the reach just upstream of the end of the upper guard wall (Plates 1-3). Strong crosscurrents developed upstream of the locks due to flow moving from the right side of the channel toward the dam. The velocities of the

crosscurrents near the end of the wall ranged from about 1.2 fps with the low flow to more than 4.0 fps with the high flow. Current velocities in the lock approach, about 1200 ft upstream of the end of the upper guard wall, varied from a maximum of about 1.3 fps with the 32,000-cfs flow to about 4.5 fps with the 203,000-cfs flow.

18. Navigation conditions for downbound tows approaching the locks during the higher flows would be difficult and hazardous, particularly for the larger tows, because of the effects of the crosscurrents. Downbound tows would have to approach the locks from close along the right bank to overcome the tendency of the crosscurrents to move the head of the tow riverward (Photo 1). After the tow had approached and landed on the guide wall of the landside lock or on the guard wall of the riverside lock, there would be a strong tendency for the stern of the tow to be rotated riverward (Photo 1). Conditions for downbound tows approaching the landside lock would be extremely difficult during the higher flows because of the tendency for the tows to be moved away from the guide wall (Photo 2). Upbound tows leaving the riverside lock would experience some difficulty in moving away from the guard wall because crosscurrents would tend to move the head of the tow riverward as it passes the end of the wall. However, upbound tows with sufficient power would not encounter any serious difficulties in overcoming the effects of the adverse currents. Tows with sufficient power and steerage should encounter no serious difficulty in moving through the navigation pass with open river flows, particularly with one-way traffic.

Plan A

Description

19. Plan A was designed to improve navigation conditions by reducing the intensity of the crosscurrents in the upper lock approach. This design was the same as the original design except that the curtains between the cells in the upper guard wall were raised and their bottoms placed at el 276.0. The openings below the bottoms of the curtains were about 6.0 ft high and 6.2 ft wide (Figure 5).

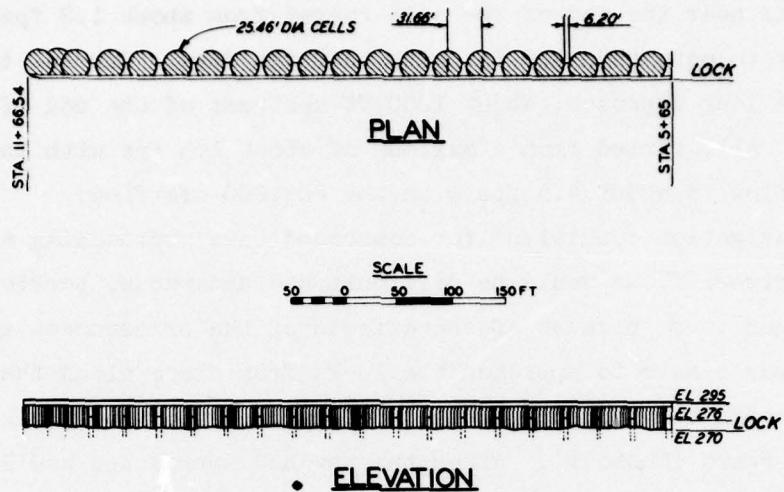


Figure 5. Design of 600-ft ported guard wall (Plan A)

Results

20. Results with Plan A indicated that the ports in the upper guard wall had no effect on water surface elevations; they were the same as those obtained with the original design (Table 1). Current directions and velocities obtained with this design were also about the same as those obtained with the original design except for the effects of flow through the ports in the upper guard wall. Most of this flow moved toward the wall at a rather sharp angle with some reduction in the outdraft near the end of the wall (Plate 4). Velocities in the approach were slightly higher than with the original design and ranged from about 1.4 to 4.8 fps.

21. Navigation conditions with this design were somewhat better than with the original design; there was some reduction in the tendency for the head of a downbound tow to be moved riverward of the end of the guard wall. However, downbound tows would continue to experience difficulties in making a satisfactory approach because of the alignment of the currents approaching the guard wall and the tendency for tows to be rotated clockwise after landing on the wall. Upbound tows would experience less difficulty in moving away from the guard wall because of reduction in crosscurrents intensities near the end of the guard wall.

Flow through the ports had little or no effect on navigation through the navigation pass with open river flow.

Plan B

Description

22. Plan B was a modification of Plan A designed to eliminate some of the navigation difficulties indicated in the results for Plan A. The design was the same as that for Plan A except for the following (Figure 6):

- a. The guard wall was extended upstream to station 17+74.04. The extended portion of the guard wall had 14 ports, each 15.04 ft wide, with tops at el 276.0.
- b. The curtains in the remaining portion of the guard wall were raised 5 ft (bottoms of curtains at el 281.0).

Results

23. Table 2 shows that this design had little effect on water surface elevations with the lower flows; with the higher flows, water levels were about 0.1 to 0.2 ft higher just upstream of the dam. Results shown in Plate 5 indicate a considerable improvement in the alignment of the currents approaching the upper guard wall compared with those obtained with Plan A. Most of the flow intercepted by the guard wall was passed through the ports with little indication of

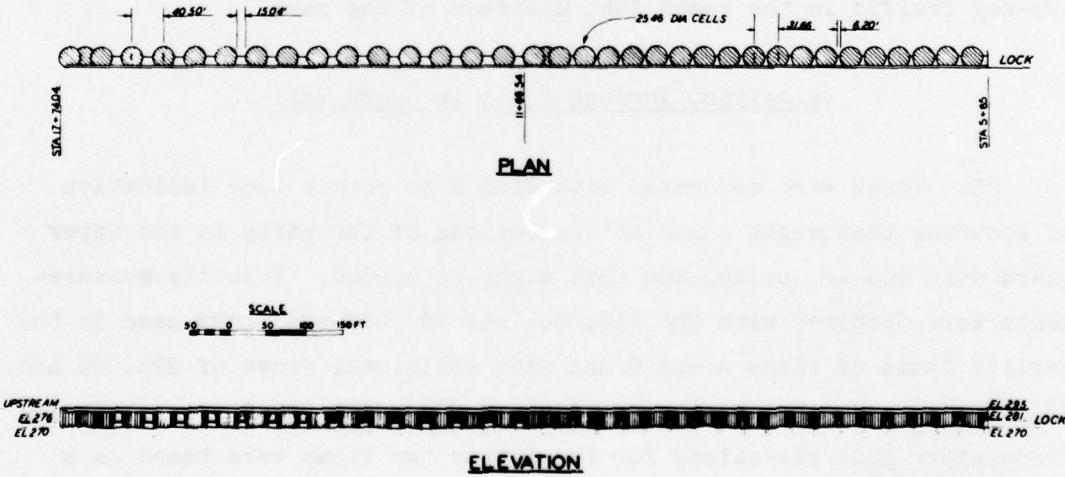


Figure 6. Design of 1200-ft ported guard wall (Plan B)

crosscurrents near the upper end. The velocities of currents moving toward the guard wall were somewhat less than those with Plan A, ranging from a maximum of 1.2 fps with the 32,000-cfs flow to about 3.5 fps with the 203,000-cfs flow. The eddy along the right bank in the approach was larger than with Plan A, but velocities in the eddy were low and mostly less than 0.5 fps.

24. Navigation conditions with Plan B were considerably better than with Plan A, particularly for downbound tows approaching the locks. A satisfactory approach to the riverside lock could be made even by tows moving a considerable distance from the right bank (Photos 3 and 4). Tows approaching the landside lock would tend to be moved toward the riverside guard wall by currents and might require some assistance in approaching the guide wall of the landside lock, particularly with the larger tows. Upbound tows should experience no serious difficulties in leaving either of the two locks (Photos 5 and 6). There was some tendency for upbound tows to be moved toward the approach for the riverward lock after leaving the landside lock. However, the effect was small and could be easily overcome with adequate power to move the load against the currents encountered in the open river. Navigation through the navigation pass in the dam was satisfactory for both upbound and downbound tows. There would be a tendency for upbound tows to be moved toward the left side of the channel which should be considered with two-way traffic in the reach just upstream of the pass.

Velocities Through Ports in Guard Wall

25. Tests were conducted with Plan B to obtain some indication of scouring that might occur at the bottoms of the ports in the upper guard wall and any protection that might be needed. Velocity measurements were obtained with the 110,000- and 203,000-cfs flows used in the earlier tests of Plans A and B and with additional flows of 225,000 and 283,000 cfs and upper pool elevations of 293.0 and 296.0, respectively. These upper pool elevations for the latter two flows were based on a low flow for the Mississippi River, which affects river stages in the

Lock and Dam 53 pool during open river conditions.

26. The results of tests shown in Plates 6 and 7 indicated that scouring could occur at the bottoms of some of the ports, depending on the erodibility of the material forming the channel bed. The higher velocities, for all flows tested, were measured on the river side near the downstream end of the guard wall and ranged from about 7.0 to 12.2 fps. Velocities were generally high through all ports, especially the smaller ports in the first 600-ft length of guard wall adjacent to the lock; the highest velocities were measured with the 225,000-cfs flow. Scouring which was not simulated in the model could affect the distribution of flow through the ports and velocities.

PART IV: DISCUSSION OF RESULTS AND CONCLUSIONS

Limitations of Model Results

27. The analysis of the results of this investigation is based principally on a study of (a) the effects of various lengths of upper guard wall and modifications to port sizes in the wall on water surface elevations and current directions and velocities, and (b) the effects of resulting currents on the behavior of the model towboat and tow. In evaluating test results, consideration should be given to the fact that small changes in directions of flow or in velocities are not necessarily changes produced by modification in design since several floats introduced at the same point may follow a different path and move at slightly different velocities because of pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to a depth of a loaded barge (9 ft in prototype) and are indicative of the currents that would affect the behavior of tows.

28. The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water surface elevations within an accuracy greater than ± 0.1 ft in prototype. Also, the model limits did not include all of the floodway areas covered by the higher flows and included only part of the overflow weir along the left overbank. The model was of the semifixed-bed type and was not designed to simulate the movement of sediment in the prototype; therefore, changes in channel configurations and slopes resulting from changes in the channel bed and banks that might be caused by the structure or changes in flow conditions could not be developed naturally. It should also be considered that water surface elevations measured were affected by the roughness of the bed which could not be adjusted and by the locations of the gages, particularly the gage near the dam and the gage just upstream of the locks.

Summary of Results and Conclusions

29. The following results and conclusions were developed during the study:

- a. Navigation conditions in the approach to the existing 600-ft lock were affected by currents from along the right bank moving toward the dam across the approach. With the construction of the temporary lock, the crosscurrents, which had to move farther to the left, increased in intensity making navigation conditions extremely difficult and hazardous with some flows.
- b. With the original design, all flow intercepted by the upper guard wall had to move riverward, creating a serious outdraft near the end of the wall. Downbound tows would have to approach the guard wall of the new lock at a rather sharp angle from close along the right bank and would tend to be rotated clockwise after landing on the wall. Upbound tows would experience some difficulty in moving away from the wall because of the currents moving across the approach.
- c. Opening of the spacings between the cells of the guard wall as in Plan A would not permit sufficient flow through the openings to have any significant effect on navigation conditions in the approach.
- d. Extension of the guard wall with sufficient ports to pass most of the flow intercepted by the wall as in Plan B would eliminate most of the outdraft near the end of the wall and provide satisfactory navigation conditions in the approach for tows using the larger lock. Conditions for downbound tows using the landside lock would be better than with the original design. However, downbound tows using the landside lock could experience some difficulty in approaching the guide wall under high-velocity conditions because of the currents moving toward the ports in the guard wall of the riverside lock.
- e. No serious difficulties were indicated for tows with sufficient power and steerage in navigating through the navigation pass during open river flows.
- f. Velocities through the ports in the upper guard wall of the riverside lock indicated that some scouring could occur, particularly at the bottoms of the ports closest to the lock. Any substantial scouring at the bottoms of the ports could affect the distribution of flow and velocities through the ports.

Table 1
Water Surface Elevations With the Original Design

| Gage No. | Water Surface Elevation, ft (msl), for Cited Discharge | | |
|-------------|--|--------------------|--------------------|
| | <u>32,000 cfs</u> | <u>110,000 cfs</u> | <u>203,000 cfs</u> |
| 1 | 290.4 | 292.6 | 298.0 |
| 2 | 290.3 | 292.0 | 297.1 |
| 3 | Dry | Dry | 296.7 |
| 4 | 290.0* | 290.0* | 294.2* |
| 5 | -- | -- | 294.2 |

* Controlled elevation.

Table 2
Water Surface Elevations With Plan B

| Gage No. | Water Surface Elevation, ft (msl), for Cited Discharge | | | | |
|-------------|--|--------------------|--------------------|--------------------|--------------------|
| | <u>32,000 cfs</u> | <u>110,000 cfs</u> | <u>203,000 cfs</u> | <u>225,000 cfs</u> | <u>283,000 cfs</u> |
| 1 | 290.4 | 292.6 | 298.0 | 297.3 | 300.2 |
| 2 | 290.3 | 292.1 | 297.2 | 296.3 | 299.2 |
| 3 | Dry | Dry | 296.9 | 295.5 | 298.5 |
| 4 | 290.0* | 290.0* | 294.4 | 293.0* | 296.0* |
| 5 | -- | -- | 294.2* | 292.9 | 296.0 |

* Controlled elevation.

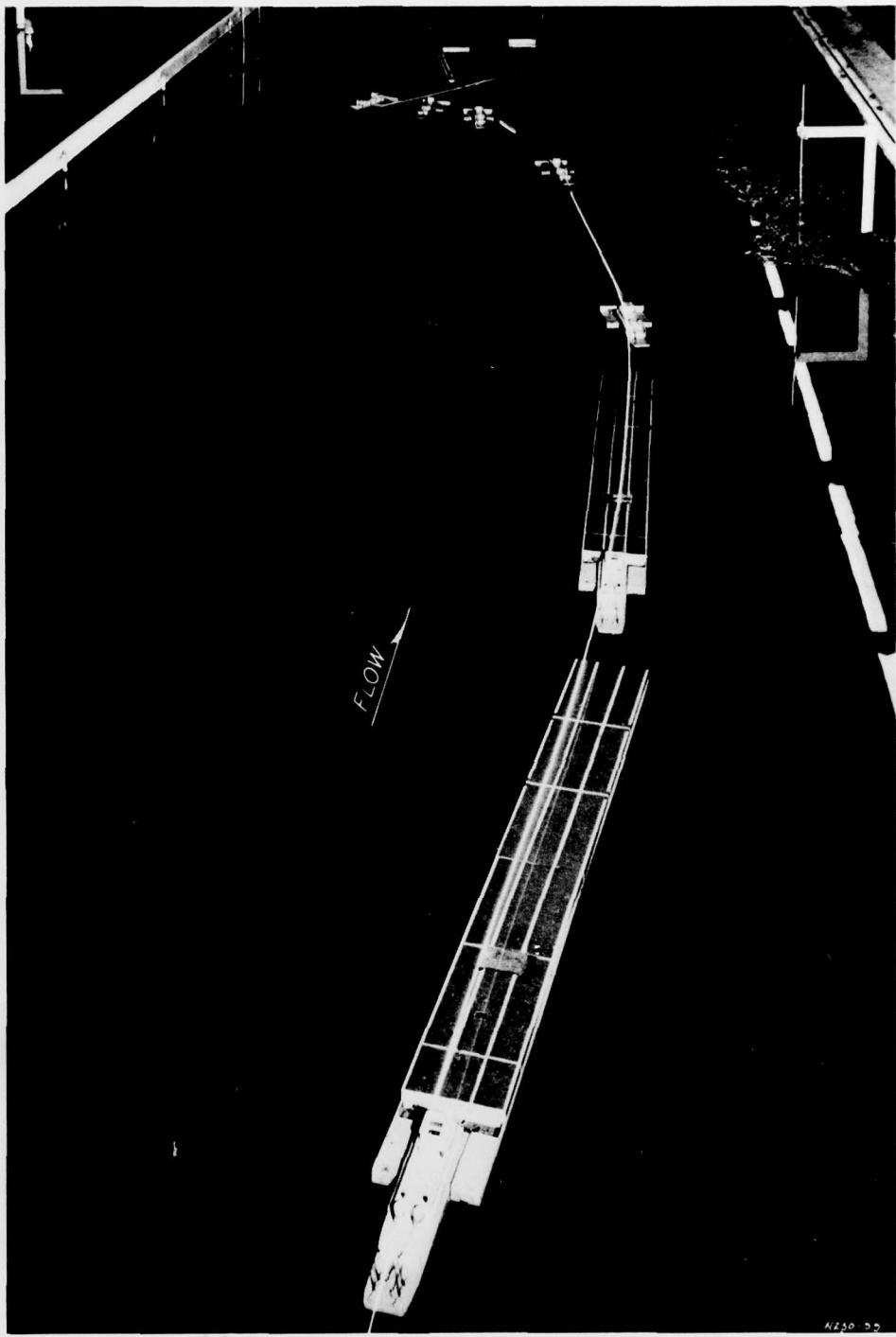


Photo 1. Original design. Discharge 110,000 cfs; upper pool el 290.0. Path of downbound tow approaching the new lock. Note tendency for tow to be rotated after landing on the guard wall

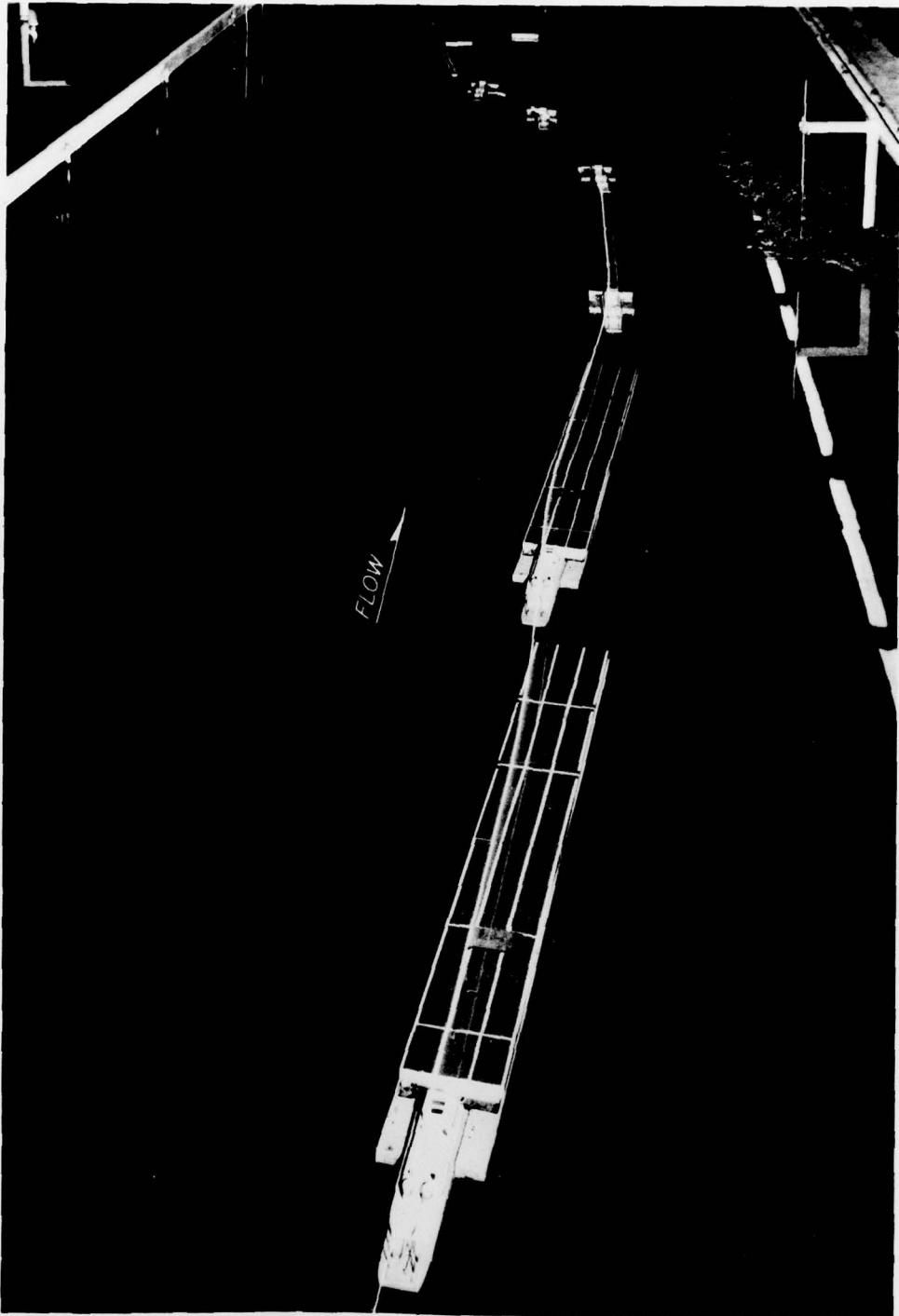


Photo 2. Original design. Discharge 110,000 cfs; upper pool el 290.0. Path of large tow attempting to approach the guide wall of the existing 600-ft lock. Note tendency for tow to be moved into the approach of the riverside lock

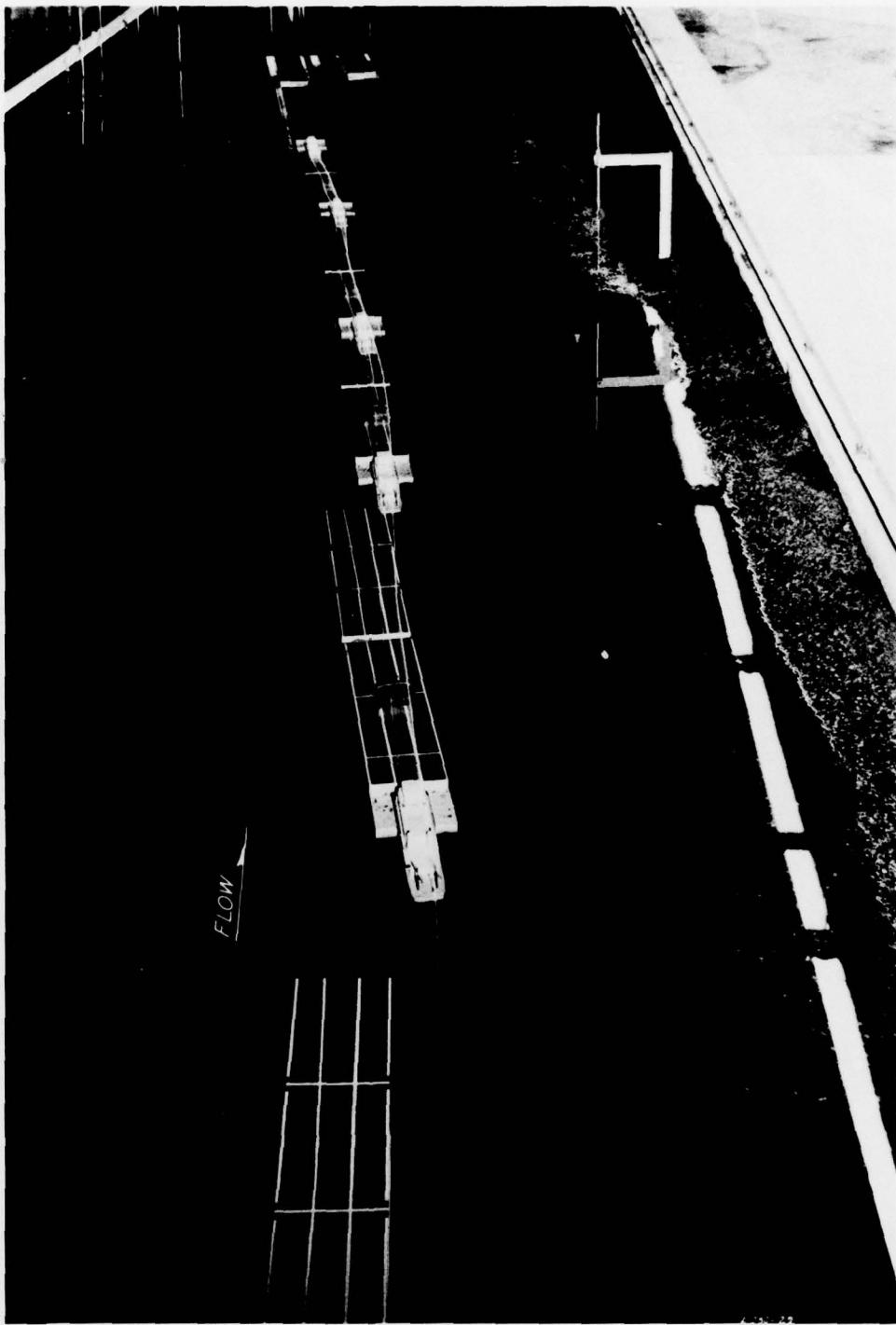


Photo 3. Plan B. Discharge 110,000 cfs; upper pool el 290.0. Path of downbound tow approaching the riverside lock. Note distance from right bank that tow can approach the lock with little effect from outdraft

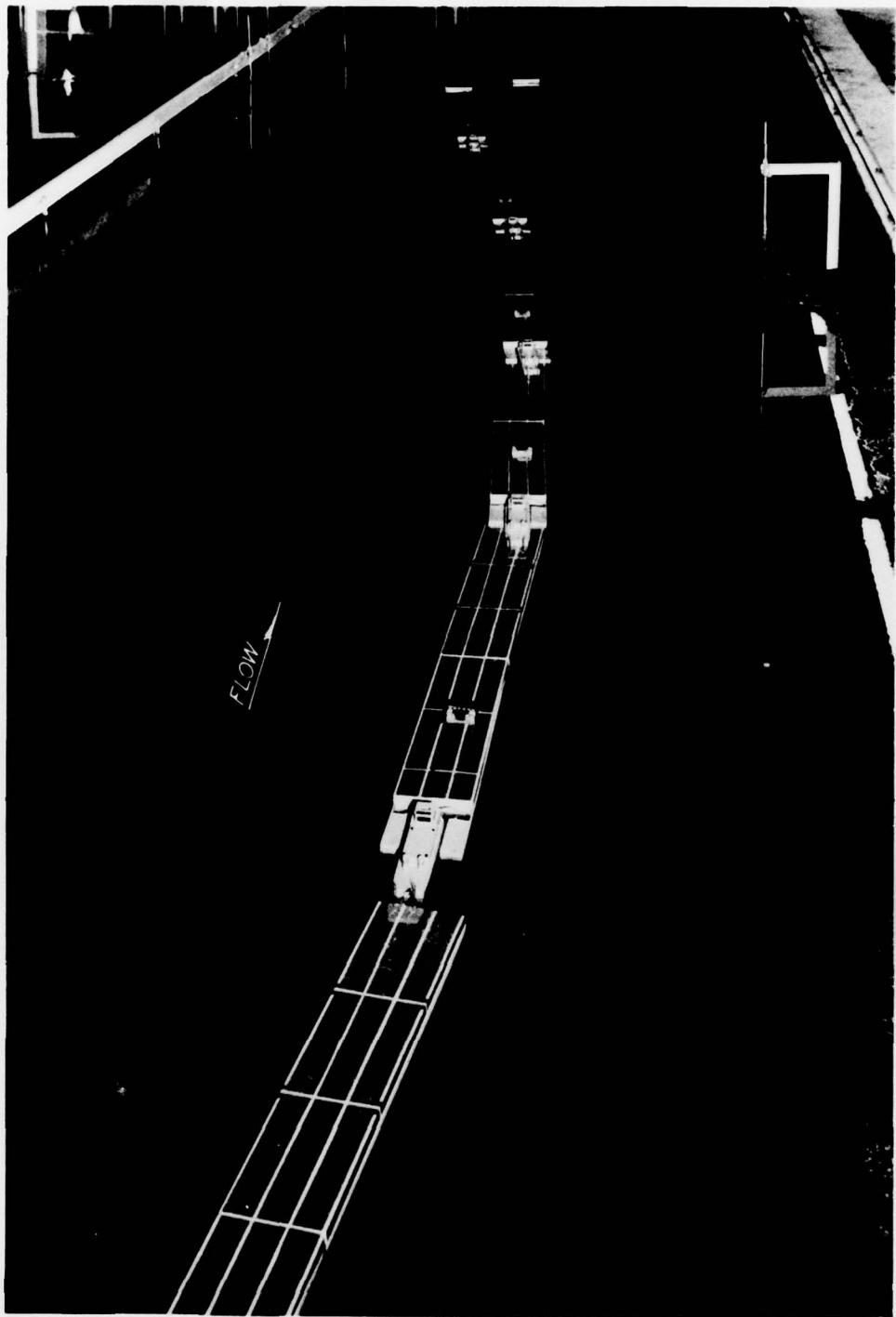


Photo 4. Plan B. Discharge 203,000 cfs; upper pool el 294.4.
Path of tow approaching the guard wall of the riverside lock
from a considerable distance riverward of the right bank

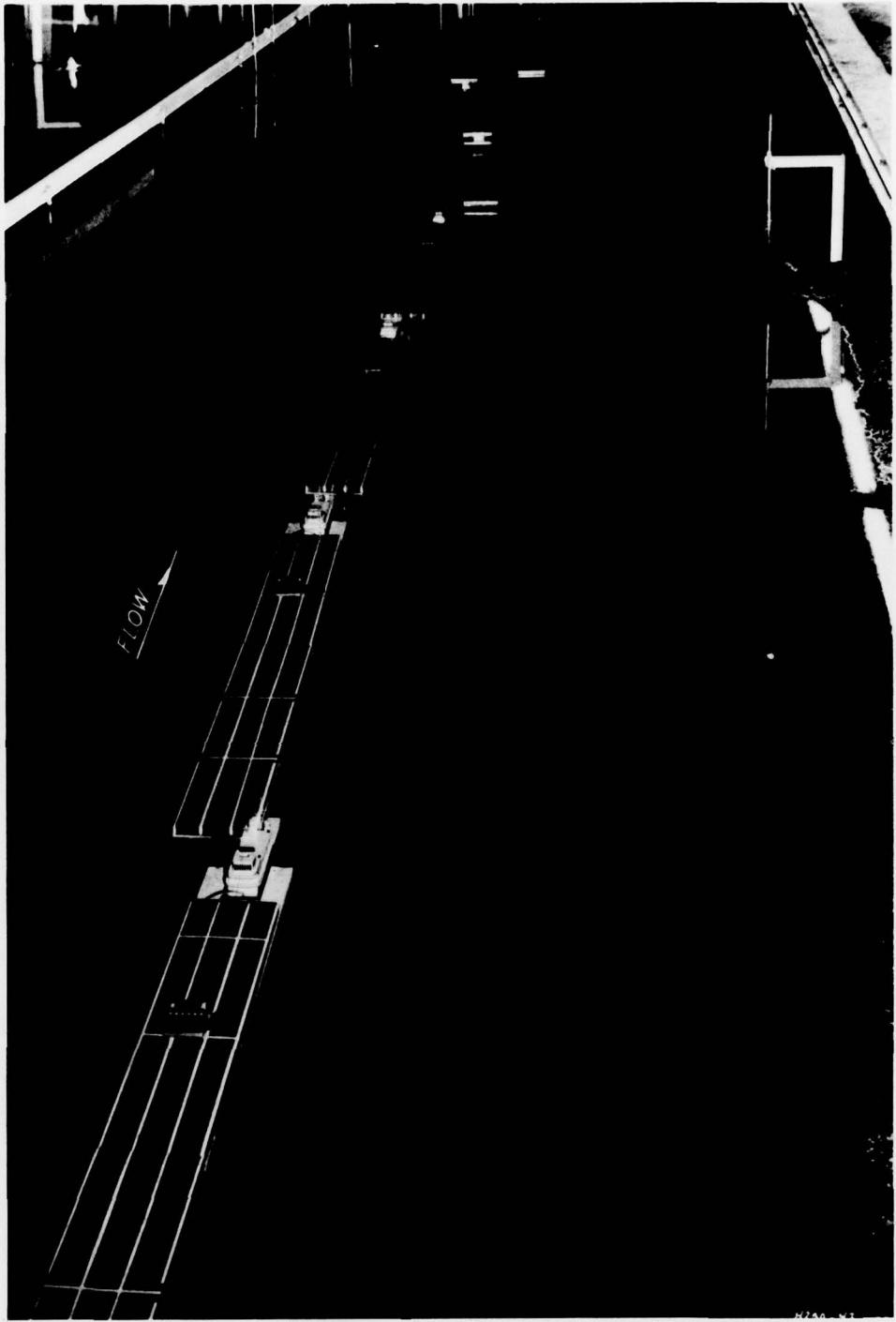


Photo 5. Plan B. Discharge 203,000 cfs; upper pool el 294.4.
Path of upbound tow leaving the riverside lock

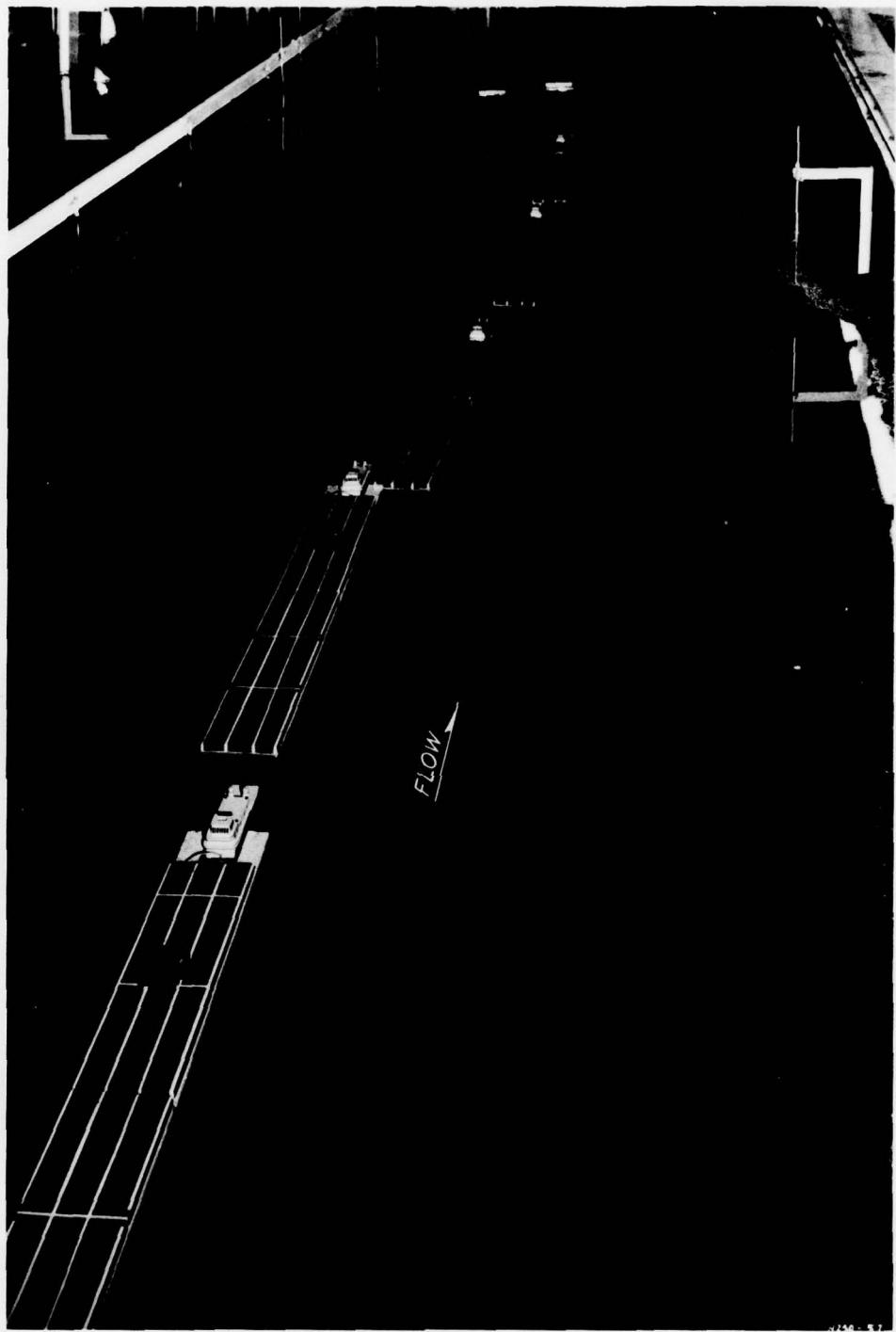


Photo 6. Plan B. Discharge 110,000 cfs; upper pool el 290.0.
Path of upbound tow leaving the landside 600-ft lock

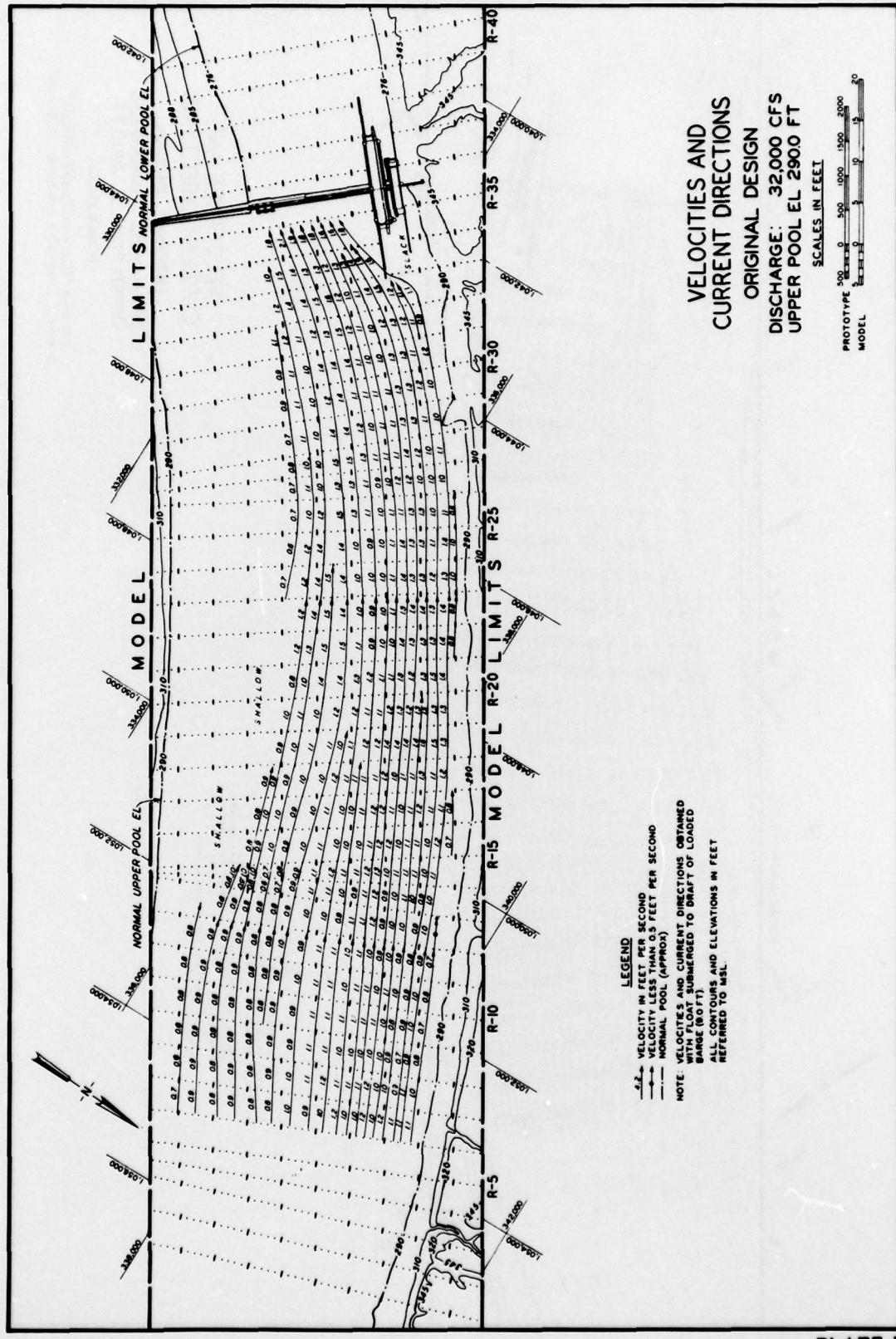
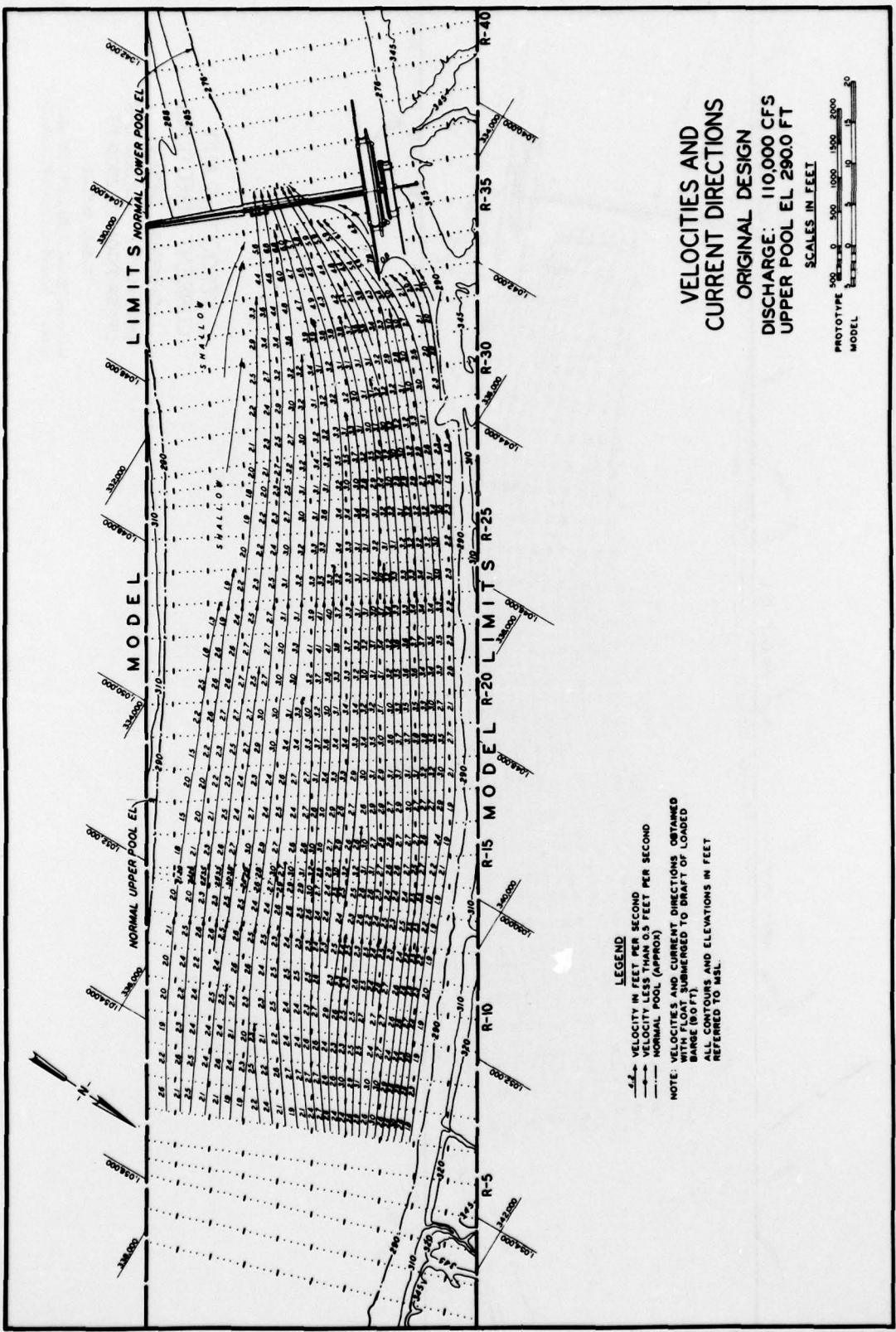


PLATE 1



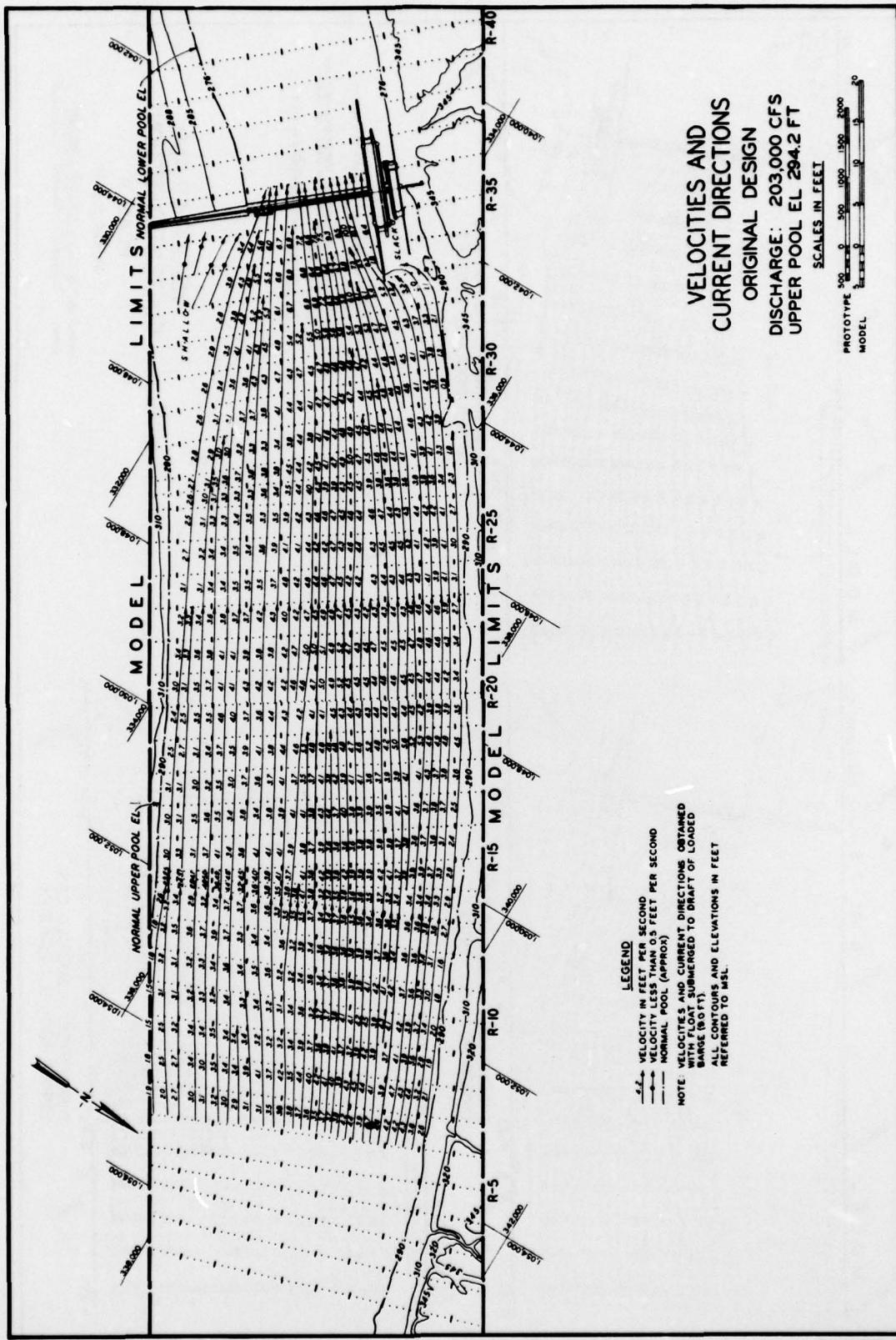
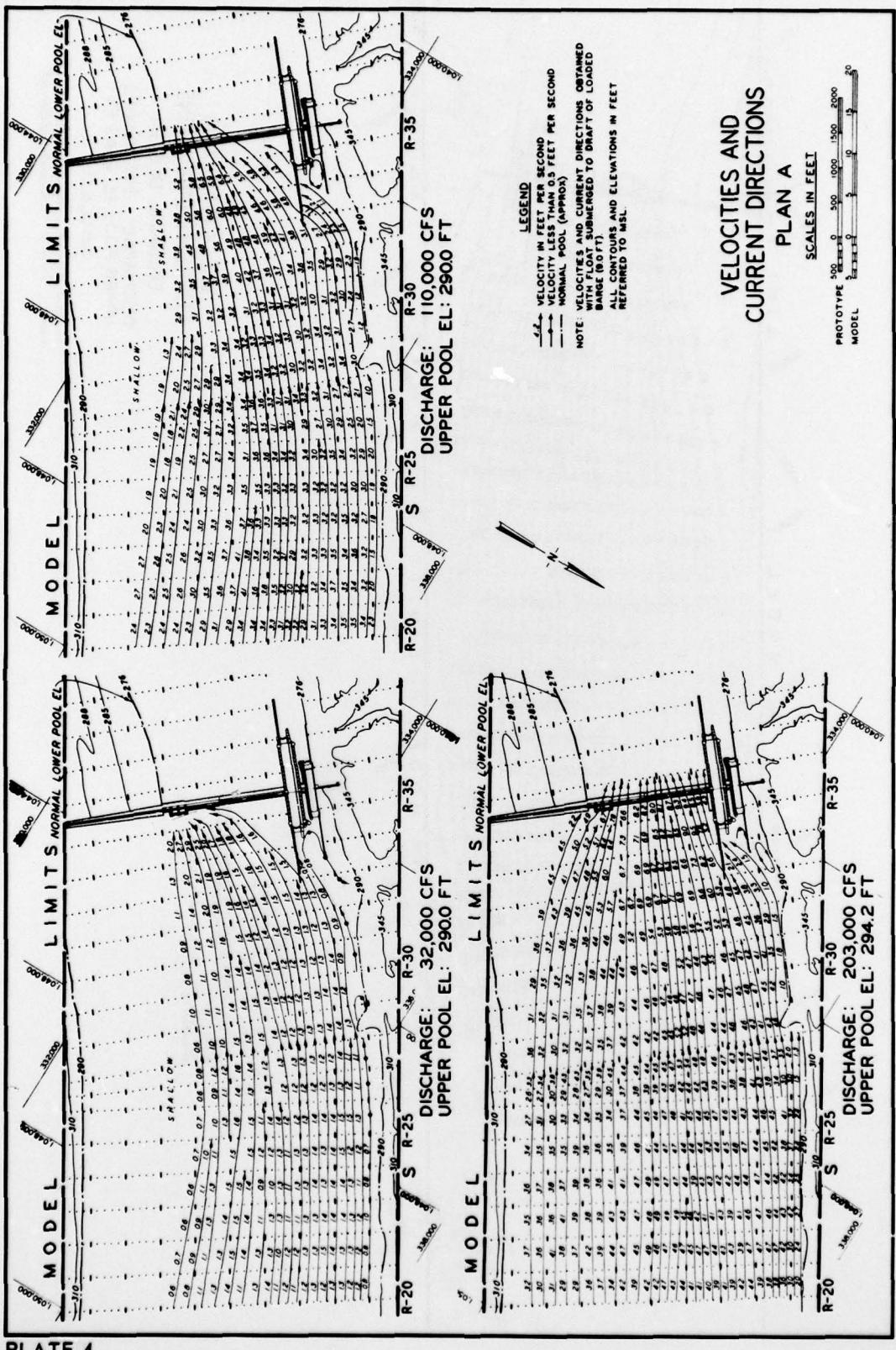


PLATE 3



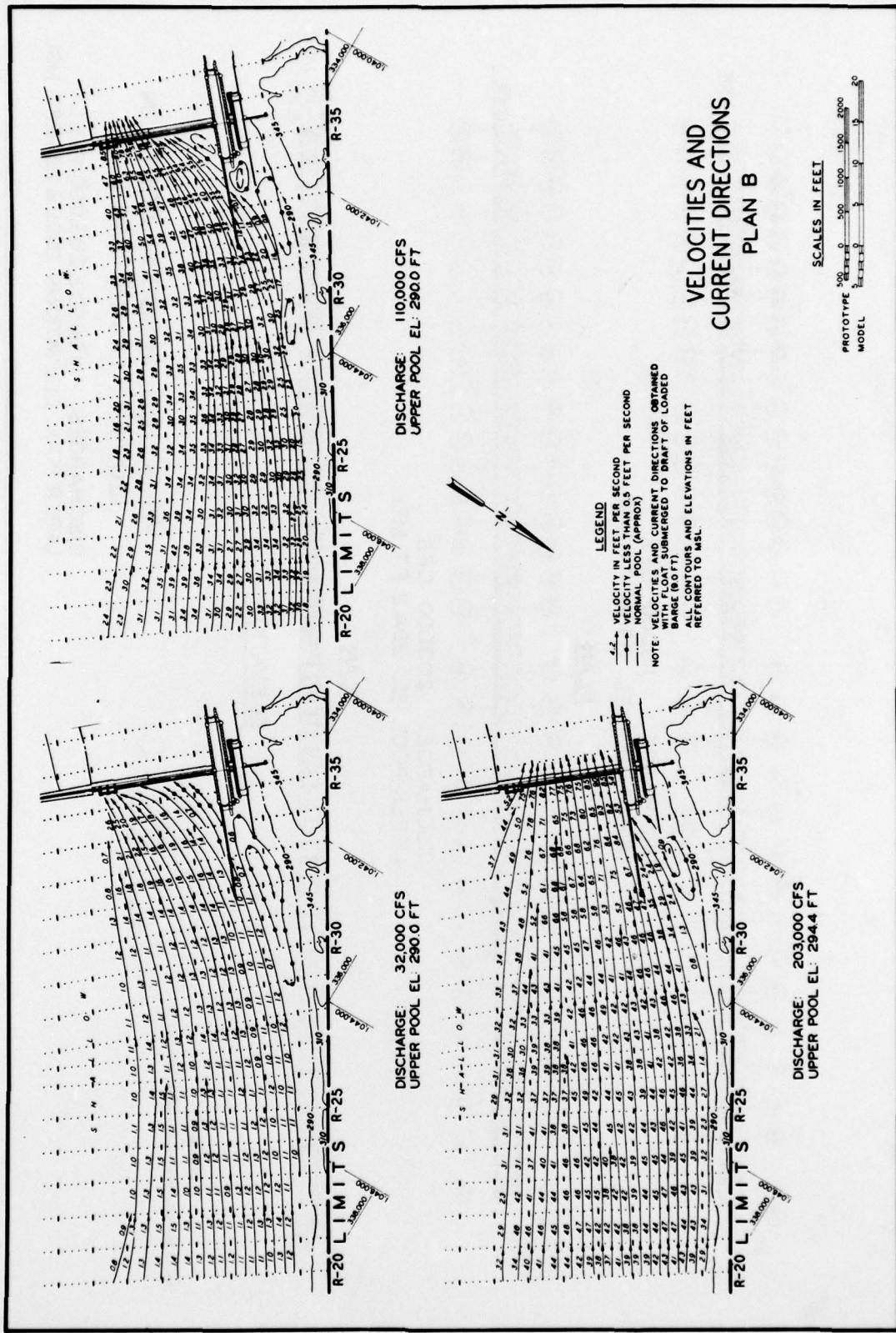
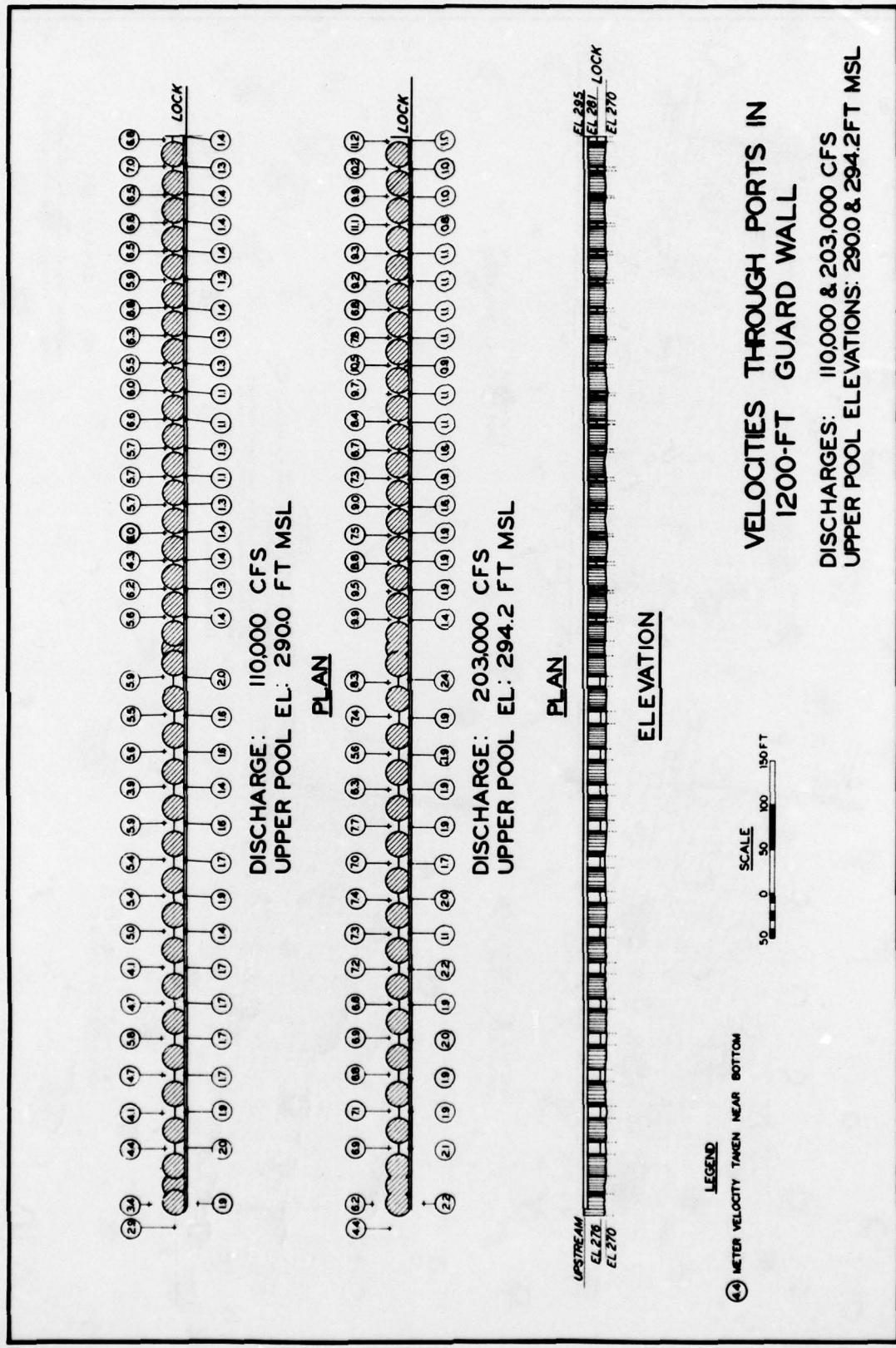
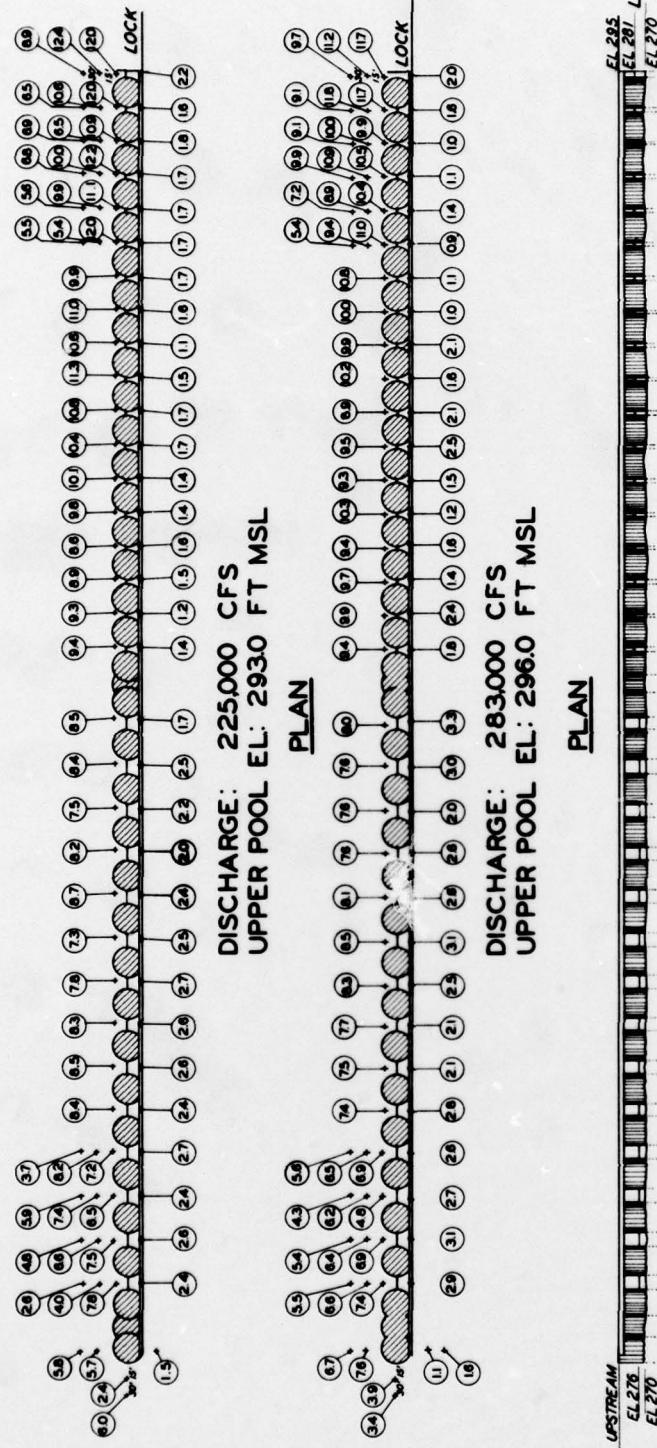


PLATE 5

PLATE 6





VELOCITIES THROUGH PORTS IN
1200-FT GUARD WALL

DISCHARGES: 225,000 & 283,000 CFS
UPPER POOL ELEVATIONS: 2930 & 2960 FT MSL

SCALE 150 FT

LEGEND

PLATE 7

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Show, Louis J

Navigation conditions at Lock and Dam 53, Ohio River, Kentucky and Illinois; hydraulic model investigation / by Louis J. Show, John J. Franco. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.

21, [7] p., 7 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-79-14)

Prepared for U. S. Army Engineer District, Louisville, Louisville, Ky.

1. Hydraulic models. 2. Lock and Dam No. 53, Ohio River.
 3. Locks (Waterways). 4. Navigation conditions.
- I. Franco, John J., joint author. II. United States. Army. Corps of Engineers. Louisville District. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-79-14.
TA7.W34 no.HL-79-14